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RELIABILITY PREDICTION OF THE AN/BQG-4 SONAR RECEIVING SET.(U)

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RELIABILITY PREDICTION OF THE AN/BQG-4 SONAR RECEIVING SET

August 1967

Prepared for
Naval Ship Engineering Center
Norfolk Division
Norfolk, Virginia
under Contract No. N00189-67-C0488

ARINC RESEARCH CORPORATION

(6) RELIABILITY PREDICTION OF THE
AN/BQG-4
SONAR RECEIVING SET.

(18) NAVSECNORDIV (19)

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ABSTRACT

Under Contract N00189-67-C0488, ARINC Research Corporation completed the following tasks on the AN/BQG-4 Sonar equipment:

- Performance of a "Method D" prediction in accordance with NAVSHIPS 93820, "Handbook for the Prediction of Shipboard and Shore Electronic Equipment Reliability"
- Identification of areas of unnecessary equipment complexity, misapplication of parts, and marginal design
- Determination of individual part replacement rates in accordance with Vitro Laboratories Technical Note 1744.00-2
- Development of a reliability block diagram for the equipment

This report documents the performance and results of the tasks.

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Under Contract N00189-67-C0488, ARINC Research Corporation completed the following tasks on the AN/BQG-4 Sonar equipment:

- Performance of a "Method D" prediction in accordance with NAVSHIPS 93820 "Handbook for the Prediction of Shipboard and Shore Electronic Equipment Reliability";

- Identification of areas of unnecessary equipment complexity, misapplication of parts, and marginal design; over

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- Determination of individual part replacement rates in accordance with Vitro Laboratories Technical Note 1744.00-2; and

- Development of a reliability block diagram for the equipment.

This report documents the performance and results of the tasks.

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SUMMARY

ARINC Research Corporation performed a "Method D" prediction on the AN/BQG-4 Sonar equipment using procedures of NAVSHIPS 93820, "Handbook for the Prediction of Shipboard and Shore Electronic Equipment Reliability." The prediction was accomplished for all modes of equipment operation.

Within the constraints of the "Method D" prediction, areas of unnecessary complexity, misapplication of parts, and marginal design were investigated.

Individual component replacement rates were determined from the failure rates predicted during the "Method D" effort. Adjustment factors for converting predicted failure rates to replacement rates were obtained from Vitro Laboratories Technical Note 1744.00-2, 30 April 1963.

Reliability block diagrams were developed for each mode of equipment operation.

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CONTENTS

1. INTRODUCTION

ARINC Research Corporation, under the provisions of Contract N00189-67-C0488, completed the following tasks on the AN/BQG-4 Sonar Receiving Set:

- Performance of "Method D" prediction in accordance with NAVSHIPS 93820, "Handbook for the Prediction of Shipboard and Shore Electronic Equipment Reliability."
- Identification, within the limits of the "Method D" prediction, of areas of unnecessary equipment complexity, misapplication of parts, and marginal design. Lists of overstressed components and document deficiencies were compiled.
- Determination of individual part replacement rates on the basis of the "Method D" predicted failure rates. Adjustment factors for converting predicted failure rates to replacement rates were obtained from Vitro Laboratories Technical Note 1744.00-2.
- Development of a reliability block diagram for each mode of equipment operation. In developing these diagrams, ARINC Research used the equipment technical information and prediction techniques presented in the following technical data package (as specified in Contract N00189-67-C0488):

  (1) Appendix F (Replacement Rate Tables) from Vitro Laboratories Technical Note 1744.00-2, 30 April 1963

  (2) NAVWEPS OP3326, Vol. 1, Sonar Receiving Set, AN/BQG-4, Description and Operation (U) (Confidential)

  (3) NAVWEPS OP3326, Vol. 2, Sonar Receiving Set, AN/BQG-4, Principles of Operation (U) (Confidential)

  (4) NAVWEPS OP3326, Vol. 3, Part 1, Sonar Receiving Set, AN/BQG-4, Maintenance (Trouble-shooting, Test, and Alignment) (U) (Confidential)

  (5) NAVWEPS OP3326 Vol. 3, Part 2, Sonar Receiving Set, AN/BQG-4, Maintenance (Schematics and References Diagrams) (U) (Confidential)

  (6) NAVWEPS OP3326 Vol. 3, Part 3, Sonar Receiving Set, AN/BQG-4 Maintenance (Disassembly, Repair, and Replacement Procedures) (U) (Confidential)

(7) Allowance Parts List for AN/BQG-4 (Identification No. 006210297)

(8) NAVSHIPS 93820, Handbook for the Prediction of Shipboard and Shore Electronics Equipment Reliability

For the assignment of failure rates and replacement rates to equipment components, data in the referenced documents were used. Where these documents did not provide failure or replacement rates for specific components, ARINC Research obtained these rates from other authoritative sources.

2. APPROACH

The basic Method "D" prediction techniques are presented in the NAVSHIPS 93820 Handbook. These prediction procedures were incorporated into a comprehensive equipment-analysis program designed to provide detailed equipment failure-rate data, MTBF figures, individual part replacement rates, equipment and document problem areas, and realistic mode-of-operation reliability block diagrams.

A functional reliability diagram was constructed for each mode of operation. These diagrams depict the effect of failure of items of equipment on the system's functional capability. They were developed through analysis of the functional relationships among items of equipment, schematics, and descriptions of the system's operation.

A functional block (FB) includes items of equipment that are required to perform a function. A functional-block group (FBG) includes functional blocks that are required to perform a higher-level function, and thus it is more complex than an individual functional block.

The components comprising each reliability functional block are listed in the appendix by circuit symbol within part type, within functional-block subdivision. The listings include severity levels,* failure rates, and replacement rates.

* Component severity level is the ratio between actual component electrical rating (volts, amperes, watts) and the applied stress, expressed as a percentage.

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3. FINDINGS

3.1 "Method D" Prediction

3.1.1 Failure Rates Obtained by ARINC Research

Two failure rates required to complete the AN/BQG-4 reliability prediction were not available from the Vitro reference. A failure rate for the high-voltage power supply, MP-4 (7.5-kV CRT supply), was derived from an observed failure rate of a similar 7.5-kV CRT supply.* This observed failure rate was adjusted according to MIL-STD-756A by the appropriate use-environment factor (0.154).** The resultant failure rate of 16.64 failures per million hours was used in calculating the AN/BQG-4 system MTBF.

A failure rate of $0.033/10^6$ hours was assigned to the magnetic heads used with the AN/BQG-4 computer drum. This rate was obtained from the following source:

Bureau of Naval Weapons

Failure Rate Data Handbook (FARADA)

U. S. Naval Ordnance Laboratory
Corona, California

Original Issue - 1 June 1962

3.1.2 Calculated Equipment Failure Rate

Table 1 is a complete tabulation of functional-block (FB) failure rates and MTBF values. The individual block and equipment failure rates and MTBF values are summations of appropriate component failure rates. Individual component failure rates are listed in the appendix under their corresponding FB tables. To facilitate calculation of the failure rate for any functional block on the reliability block diagrams, the tables have been assigned the same numeric designator as the FB blocks on the reliability diagrams.

*Final Report, Observed MTBF Values for B-58 Avionics Subsystem and Equipments, ARINC Research Publication 318-01-4-521, July 1965:

Power Supply (Indicator Console Unit), MTBF = 9251.7 Hours

Failure Rate = 108.09 Failures/10^6 Hours

**MIL-STD-756A, 15 May 1963, Military Standard Reliability Prediction, Paragraph 5.91:

Shipboard/Ground - 1.0

Manned Aircraft - 6.5

Aircraft-to-Ship Ratio - 1:0.154

TABLE 1

PREDICTED FUNCTIONAL-BLOCK FAILURE RATES AND MTBF VALUES

Functional Block	Failure Rate		MTBF	
	Calculated	Adjusted*	Calculated	Adjusted*
1. Preamplifiers	354.24	389.66	2,822	2,566
2. Clipper Amplifiers	649.94	714.93	1,539	1,399
3. Control Console (B+)	179.88	197.87	5,559	5,054
4. Control Console (Low Voltage) and Cabinet	198.64	218.50	5,034	4,577
5. Control Console (High Voltage) and Cabinet	30.67	33.74	32,605	29,638
6. Signal Comparator (B+)	23.81	26.19	41,999	38,183
7. Signal Comparator (Low Voltage)	144.55	159.01	6,918	6,289
8. Deltics	690.83	759.91	1,448	1,316
9. Heater Amplifiers	116.14	127.75	8,610	7,828
10. Deltic Reclock Amplifiers	198.72	218.59	5,032	4,575
11. Correlator and Counters	578.85	636.74	1,727	1,570
12. Input Registers and Arithmetic Unit	306.65	337.32	3,261	2,965
13. Integrator and Decoder	589.35	637.29	1,726	1,569
14. Drum Circuits	1172.90	1290.19	8,525	7,751
15. Synchronizers	376.31	413.94	2,657	2,416
16. Clock and Pulse Generator	241.99	266.19	4,132	3,757
17. Filter	11.76	12.94	85,034	77,280
18. High-Speed Synchronizers	107.20	117.92	9,328	8,480
19. Error Card and Cabinet	203.48	223.83	4,914	4,468
20. Timing Circuits (Targets A and B)	2718.36	2990.20	368	334
21. R_q and B_q Computer (Targets A and B)	1073.98	1181.38	931	847
22. Acquisition Scope (Targets A and B)	220.38	242.42	4,538	4,125
23. Main Scope	353.89	389.28	2,826	2,569
24. Test Equipment and Nonessential Parts	391.06	430.17	2,557	2,325
Summation:	10,923.58	12,015.96	-----	-----
Overall System MTBF ($\frac{10^6}{\text{Failure Rate}}$):	-----	-----	91.54	83.22

*Adjustment Factor = 1.1.

3.1.3 Calculated Equipment MTBF

In the calculation of MTBF values the appropriate design failure-rate summation was multiplied by the applicable adjustment factor (1.1 for Sonar equipment)* listed in NAVSHIPS 93820.

The overall AN/BQG-4 system should display an MTBF of 83.22 hours based on a combined equipment failure rate of 12015.96 failures per million hours. The MTBF values for the single and multiple target modes are 115.7 hours (λ = 8643.13 failures per million hours) and 86.31 hours (λ = 11,585.79 failures per million hours), respectively.

3.2 Equipment/Document Deficiencies

3.2.1 Areas of Unnecessary Equipment Complexity and Marginal Design

The investigation of equipment complexity and marginal design was conducted within the limits of the "Method D" prediction. The depth of analysis was of necessity not that of a separate design-analysis program. Within this constraint, the ARINC Research effort revealed the following areas of questionable equipment complexity.

- Most circuits within the AN/BQG-4 are of solid-state design. However, several vacuum-tube circuits are used. State-of-the-art advances in transistor performance in high-frequency and high-voltage applications can be employed to eliminate the vacuum-tube circuits. Simple and more reliable solid-state circuits can be developed to perform the function of the master-clock frequency generator, the sample pulse generator, the deltic reclock amplifier, and Deltics AD-1 and AD-2. On the basis of tube and transistor failure rates in NAVSHIPS 93820, the failure rates of these circuits can be reduced by a factor of six to one through solid-state redesign.

- The influence of rate of operation (cycling) in determining the overall failure rate of relays is explained in MIL-HDBK 217A, 1 December 1965. Analysis of the operation of relay K-1 in the delay-line heater-control amplifier indicates that this cycling factor would increase the failure rate of the relay. If maintenance records confirm a high removal rate for this component, consideration should be given to selecting a replacement relay. One method of expediting maintenance on this circuit is to change the relay installation from a solder-in to a plug-in configuration.

- The effectiveness of the redundant multiple-target tracking capability of the AN/BQG-4 system could not be realistically evaluated without detailed information on complete tactical application of the system. However, on

*The adjustment factors in NAVSHIPS 93820 are included to compensate for adjustment-type failures associated with four general categories of equipment.

the basis of these tactical application data, a decision could be made to reduce overall system complexity by eliminating all or part of this redundant function.

3.2.2 Parts Misapplication

The presentation of parts-misapplication (marginal-design) data is restricted to the listing of those parts found to be stressed in excess of 70 percent* of the maximum design rating. This listing is presented in Table 2.

The stress level for all equipment components is indicated in the work-sheet tables presented in the appendix.

3.2.3 Document Deficiencies

Obvious errors in the technical documents applicable to the AN/BQG-4 equipment are described in Table 3. The following are also considered inadequacies of these documents:

- An essential troubleshooting tool normally included in technical publications of this type has been omitted. This tool is a table of static-voltage and resistance readings for each electron tube used in the equipment.

- Wiring diagrams as exemplified by Figure 7-95, pages 7-278 to 7-281, NAVWEPS OP3326, Volume 3, Part 2, Sonar Receiving Set, AN/BQG-4 Maintenance, are completely unacceptable for troubleshooting utilization because of their format and print size.

- A descriptive parts list (similar to NAVSHIPS 93530, Volume 3, Section 7) for components of the AN/BQG-4 equipment is not included in the technical documents. The absence of this listing seriously hampers engineering analysis of the equipment and must also complicate maintenance and troubleshooting efforts.

- In many of the schematics of NAVWEPS OP3326, the values for components are unreadable.**

3.3 Part Replacement Rates

Part replacement rates were taken from Vitro Laboratories Technical Note 1744.00-2. The most striking omission from this document was that of the replacement rate for transistors. After extensive review of transistor application and

*This level was established during a meeting of ARINC Research and NAVSECNORDIV Reliability Engineering Division representatives, 28 February 1967.

**For example:

Figure	Component
7-30	R-59, R-74, R-76
7-34	R-70
7-60	R-56

TABLE 2

OVERSTRESSED COMPONENTS, AN/BQG-4

Component Location	Circuit Symbol	Stress Level (Percent)
Hydraphone Preamplifier	C 2	85
	C 6	94
	C 7	94
	C 9	97
	C 14	97
Clipper Amplifier (A-12)	C 5	98
	C 9	98
(A-13)	C 4	83
	R 8	73
	R 9	143
	R 18	204
(A-18)	C 3	91
	C 6	87
(A-20)	C 6	95
	R 6	99
	R 13	99
(A-21)	C 1	70
	C 2	73
	R 5	99
Power Supply, B+ (1A3A1)	C 1	82
	C 2	94
	C 3	89
	C 4	89
	R 1	80
	R 2	80
	R 3	80
	R 4	95
	R 5	95
	R 6	75
	R 7	91
	R 8	91
	R 23	75
	R 24	75
	R 39	84
	R 42	77
	R 49	153
	R 50	153
	R 51	78
	R 52	78
Low Voltage Power Supply (A-3)	R 19	165
	R 20	165
(A-7)	R 8	320
	R 9	320
	R 10	235
Power Supply, B+ (2A2)	C 1	75
Low Voltage Power Supply (2A3)	R 31	73.5
Deltic AD 1 and AD 2	C 29	90
	C 36	75
	C 48	100
	R 24	117
	R 25	186
	V 1	73
	V 2	73
	V 3	73
	V 4	73
	V 7	73
Deltic Reclock Amplifier	C 1	75
	R 28	148
High-Speed Counter (DA 25)	R 103	76
Borrow Card and Time Gate	R 2	80
Decoder (DA 19)	R 94	84
	R 99	230
Write Amplifier (ZA1)	R 31	93
	R 32	140
	R 33	140
Read Amplifier (ZA1)	C 3	72
	C 4	72
	C 7	72
	C 8	72
	C 13	72
	C 14	72
	C 17	72
	C 18	72
	R 1	90.4
	R 5	76.8
	R 20	76.8
	R 22	90.4
	R 47	90.4
	R 51	76.8
	R 66	76.8
	R 68	90.4
	R 11	78.4
	R 33	78.4
	R 55	78.4
Drum Control Amplifier	C 8	96
	R 20	129
Signal Comparator Cabinet (2C1MP1W2...)	R 5	72
Master Clock Frequency Generator	C 25	100
	C 26	100
High-Speed Synchronizer (DA 27)	R 93	85
	R 96	85
High-Speed Synchronizer (DA 28)	R 15	70
	R 68	74
Lower Control Panel (1A4) (A2)	R 4	86
	R 5	86
	R 9	86
	R 10	86
	R 11	72.7
	R 12	72.7
(A4)	R 2	70
Resolver Driver (DA31)	C 4	80
	C 11	112
	C 24	80
	C 34	112
Main Oscilloscope	A1R5	71
Frequency Divider (VA-4)	R 7	90
	R 10	90
	V 3	71.4
Signal Source (7A1)	C 7	90
	C 10	90
Noise Source (7A2)	C 7	90
	C 9	90
Transformer Filter (7A3)	C4	90
Power Supply (7A6)	C 2	83.3
Delay Line (7A7)	C 1	75
Voltmeter (7A8)	C 8	120
	C 13	123.2
	C 14	78.4
	C 15	78.4
	C 16	90
	C 18	100
	C 23	83.3
Oscillator (7A9)	C 15	80
	R 24	124
	R 25	124
	R 26	80

TABLE 3

DOCUMENT DISCREPANCIES, AN/BQG-4 (NAVWEPS OP3326)

Location	Discrepancy
Figure 7-120, Page 7-357, Volume 3, Part 2	Indicates one CR-1 and one CR-5 installed in amplifier A3.
Figure 8-35, Page 8-52, Volume 3, Part 3	Lists two entries for diode CR-1 and two entries for diode CR-5.
Figure 7-123, Page 5-189, Volume 2	Lists R3 on resolver trim card at 196K-ohm value.
Figure 7-123, Page 7-361, Volume 3, Part 2	Shows the same R3 to be a 90.9K-ohm resistor.
Figure 7-92, Page 7-269, Volume 3, Part 2	There should be a connection at the junction of C-13, R-13, and R-14.
Figure 7-147, Page 7-142, Volume 3, Part 2	The capacitor in parallel with CR-9, CR-10, and R-25 is unidentified.
Figure 7-149, Page 7-414 Volume 3, Part 2	Capacitor C-5 is not shown on the schematic.
Figure 7-158, Page 7-423 Volume 3, Part 2	The resistor between R-19 and Q-1 is unidentified.

reliability information, the following authority was found to be both technically compatible with the current evaluation and of sufficient scope to provide realistic data:

John E. Shwop and Harold J. Sullivan,** Editors, Semiconductor Reliability Engineering Publishers, Elizabeth, New Jersey, 1961, Chapter 22, "Semiconductor Failures Versus Removals."

The transistor replacement-to-failure ratio of 2.465:1 determined from this source was used in the appendix to derive the replacement rate for all transistor entries.

A replacement rate for frequency-determining crystals is not included in the Vitro document. After careful consideration of the application of crystals in the AN/BQG-4 system (in single rather than multiple installations), it was determined that the most feasible replacement-to-failure ratio for this component would be 1:1. The correction factor of 1.5 was applied since the price of this item is less than $15.00.**

* Mr. Shwop is with the Industrial Preparedness Activity, U.S. Army Signal Supply Agency. Mr. Sullivan is a research scientist at New York University.

** Appendix F, Vitro Laboratories Technical Note 1744.00-2, 30 April 1963. The replacement rates in this document require a correction factor of 1.5 for items with a unit price of less than $15.00. For those items with a unit price of $15.00 or over, no correction factor is necessary.

3.4 Functional Reliability Diagrams

From operational data contained in NAVWEPS OP3326, Volumes 1, 2, and 3, the following modes of operation were determined: (1) single-target acquisition and tracking, and (2) multiple-target acquisition and tracking. The corresponding functional reliability diagrams are shown in Figures 1 and 2, respectively.

Two console positions are provided for target acquisition and tracking in the AN/BQG system. In this installation, a multiple-target acquisition and tracking capability is provided through duplicate timing circuits (FB 20a and 20b), R_q and B_q computer (FB21a and 21b), and acquisition oscilloscope (FB22a and 22b). The failure rates shown in Table 1 for FB 20, FB 21, and FB 22 are for the multiple acquisition and tracking capability and, therefore, are summations of the failure rates for each of the duplicated circuits.

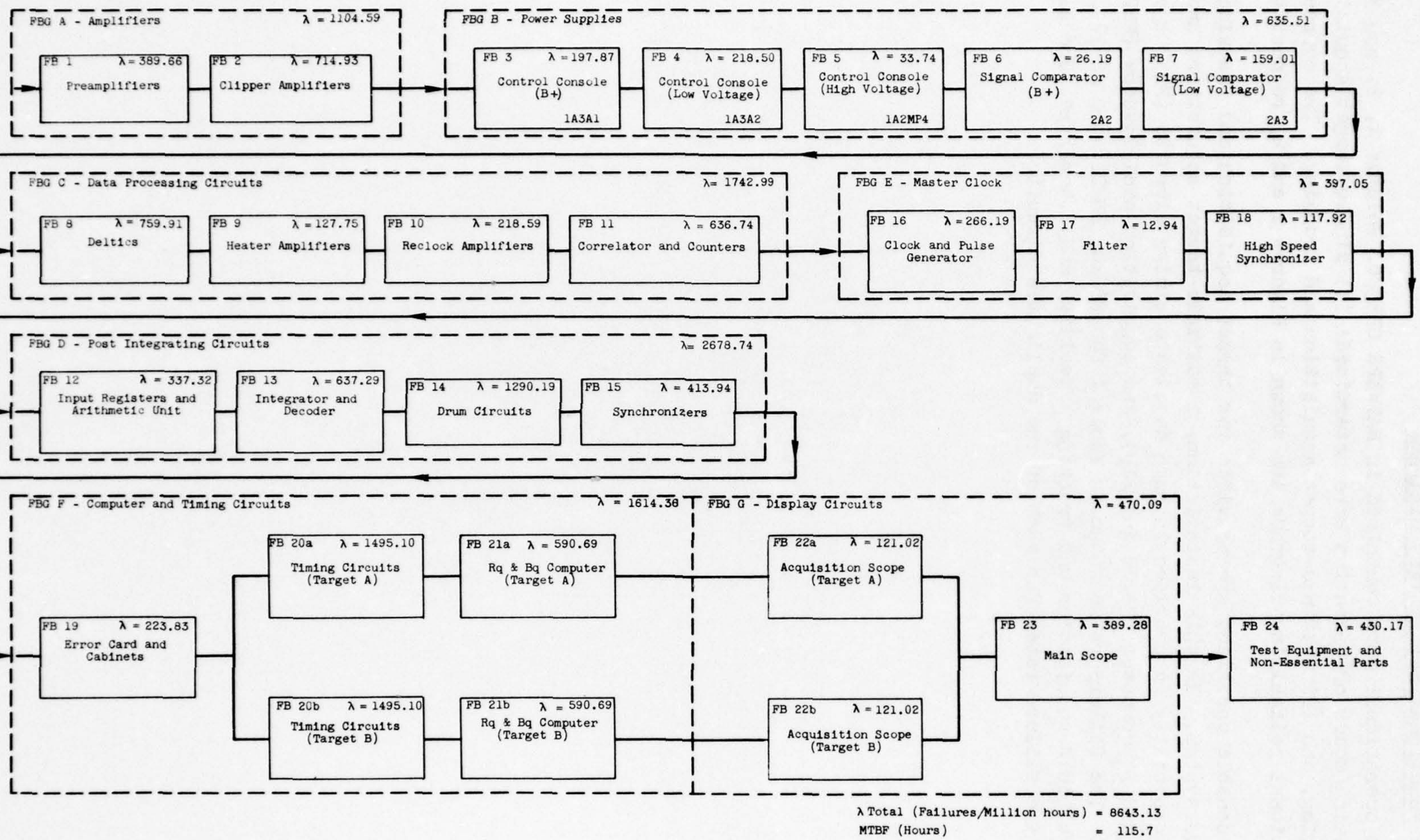
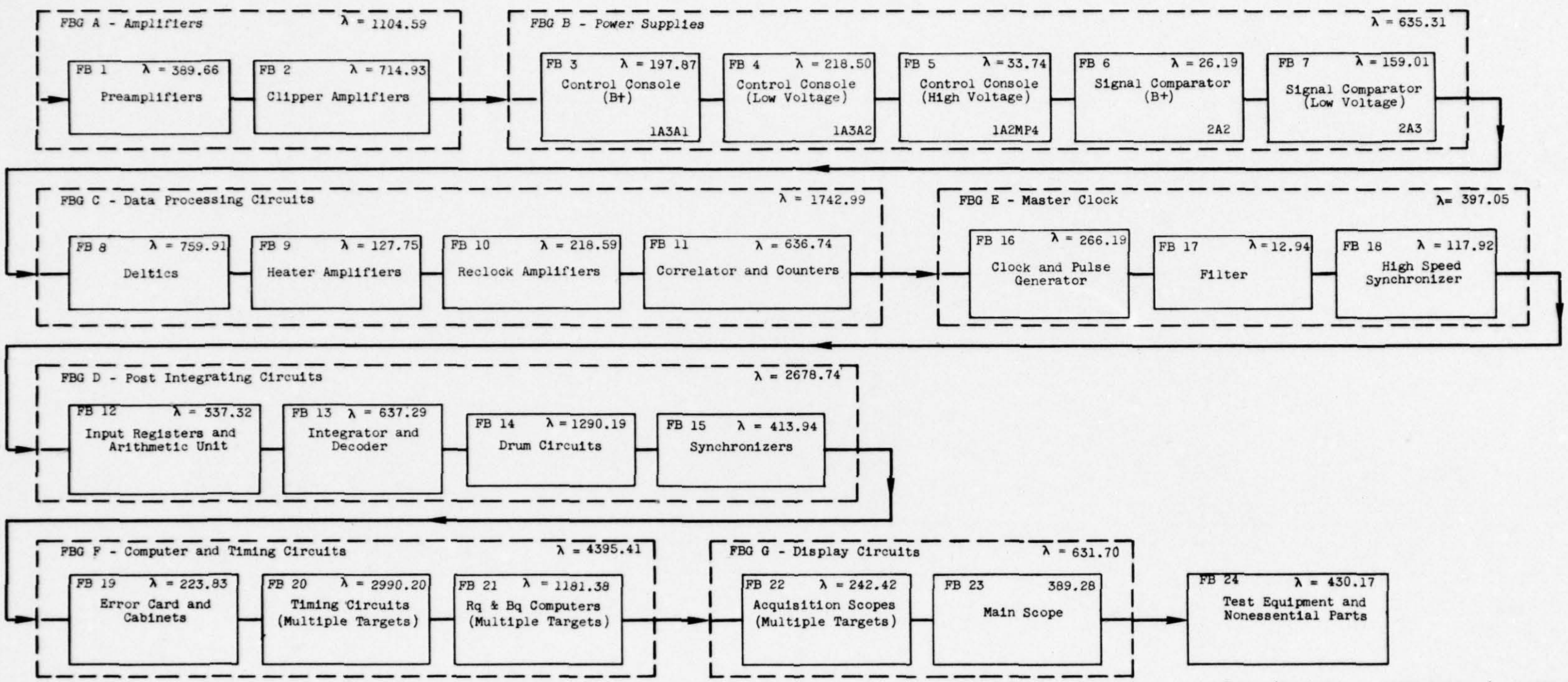


FIGURE 1

FUNCTIONAL RELIABILITY DIAGRAM, AN/BQG-4
SINGLE TARGET (ACQUISITION AND TRACKING)



λ Total (Failures per Million Hours) 11585.79
MTBF (Hours) 86.31

FIGURE 2

**FUNCTIONAL RELIABILITY DIAGRAM, AN/BQG-4
MULTIPLE TARGETS (ACQUISITION AND TRACKING)**

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4. CONCLUSIONS

The conclusions reached as a result of the tasks described in this report are as follows:

- Many components in the AN/BQG-4 equipment are stressed beyond their rated value (see Table 2).
- The actual reliability of the AN/BQG-4 equipment is expected to be slightly lower than that predicted in this report, since the overstress of many components (see Table 2) was outside the margins considered in the NAVSHIPS 93820 Handbook.
- Omission of a descriptive parts list for AN/BQG-4 components reduces the overall effectiveness of maintenance documentation since such list is vital to the description of malfunctions and to the proper maintenance of system configuration.
- Instances of design complexity and ineffective use of functional redundancy were discovered during the equipment analysis, as described in this report. However, the limited scope of the prediction task precluded a complete definition of all such areas in the AN/BQG-4 equipment.

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5. RECOMMENDATIONS

The following recommendations are offered:

- Overstressing of components in the AN/BQG-4 should be confirmed by on-equipment testing. Appropriate corrective action (part replacement, circuit redesign) should be initiated where overstress is confirmed.
- The scope of the technical documents pertinent to the AN/BQG-4 equipment should be expanded to include a current and complete descriptive parts list of equipment components.
- The feasibility of replacing currently used vacuum-tube circuits with state-of-the-art solid-state circuits should be investigated, since current prediction techniques indicate that a substantial improvement in reliability could be achieved by such replacement.
- Maintenance records concerning the performance of relay K-1 in the heater-control amplifier should be reviewed. If a high failure rate is confirmed, a substitute relay should be sought. In addition, the mounting of this relay should be changed from a solder-in to a plug-in configuration to facilitate replacement if the high replacement rate is confirmed.
- The effectiveness of, and necessity for, the multiple-tracking capability should be assessed to determine if the lowered reliability that results from the provision of this capability is justified by the improvement in system performance.

APPENDIX

WORK SHEETS

This appendix contains work sheets used to derive failure and replacement rates for the AN/BQG-4 Sonar system.

For ease in the location of components, the tables of this appendix are numbered to correspond to the functional blocks of the reliability diagrams. Components are listed in alpha-numerical order by function. A decimal point in a table number indicates additional units within the same functional block. The unit failure rates are summed, and the total failure rate for each functional block is given.